Risk Assessment of HFC 152a and Carbon Dioxide Mobile Air Conditioning Systems

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Overview

- Goal
- Participants and Partners
- Risk Assessment Approach
- Major Findings and Conclusions
- SNAP Review
- Next Steps

Purpose

- To develop an independent risk assessment for HFC-152a and Carbon Dioxide MAC systems
- Provide information for industry and policy makers worldwide
- SNAP review

Challenges

- Systems still under development
  - Many different design options
  - Many different options for mitigation
- Sparse data on component failure rates
- Conservative assumptions applied when data or specific system designs were lacking

Risk Assessment Approach

- Identify exposure thresholds of concern
- CFD Modeling (Passenger Exposure)
  - Characterize potential release into passenger compartment and potential efficacy of proposed mitigation strategies
  - Simple modeling used as initial screen
  - Full CFD analysis
- Fault Tree Analysis
  - Broadly quantify exposures with potential for injury

Carbon Dioxide is Toxic

- **Limits for passenger exposure**
  - **4% limit for sustained exposure (~one hour)**
  - **6% limit for brief exposure (minutes)**

- **Human Exposure Data**
  - **Functional impairment (5% for about an hour)**
  - **Dizziness, muscle twitching unconsciousness (7-10% exposure for a few minutes)**
  - **Unconsciousness / Death (18% for less than 1 minute)**

- **Selected References**

  - ***IDLH Documentation for Carbon Dioxide, U.S. Center for Disease Control*** ***www.cdc.gove/niosh.idlh/124389.htm***
  - ***Carbon Dioxide as a Fire Suppressant: Examining the Risks.*** ***www.epa.gov/ozone.snap.fire/co2/co2report.pdf***

HFC-152a is flammable

- Flammable in the range of 3.7% to 20%
  - Threshold-of-concern 2% for ‘perfect mixing’ modeling
  - 3.5% is the threshold used for 3D CFD
- Open flames (matches, butane lighters) are credible ignition sources in passenger compartment
  - No credible electrical ignition sources in passenger compartment
  - Based on analysis of credible ignition sources for propane and methane
  - Used in “dust-off” products and indicated for use on live circuitry

Assumptions Across CFD Scenarios

- **Large Sedan with 6 occupants**
- **Maximum possible leak from evaporator or evaporator input line** (Theoretical worst-case)
- **Windows/doors closed**
- **Stationary vehicle**
- **Infiltration/exfiltration set using US NREL datasets**

Maximum Leak Rates

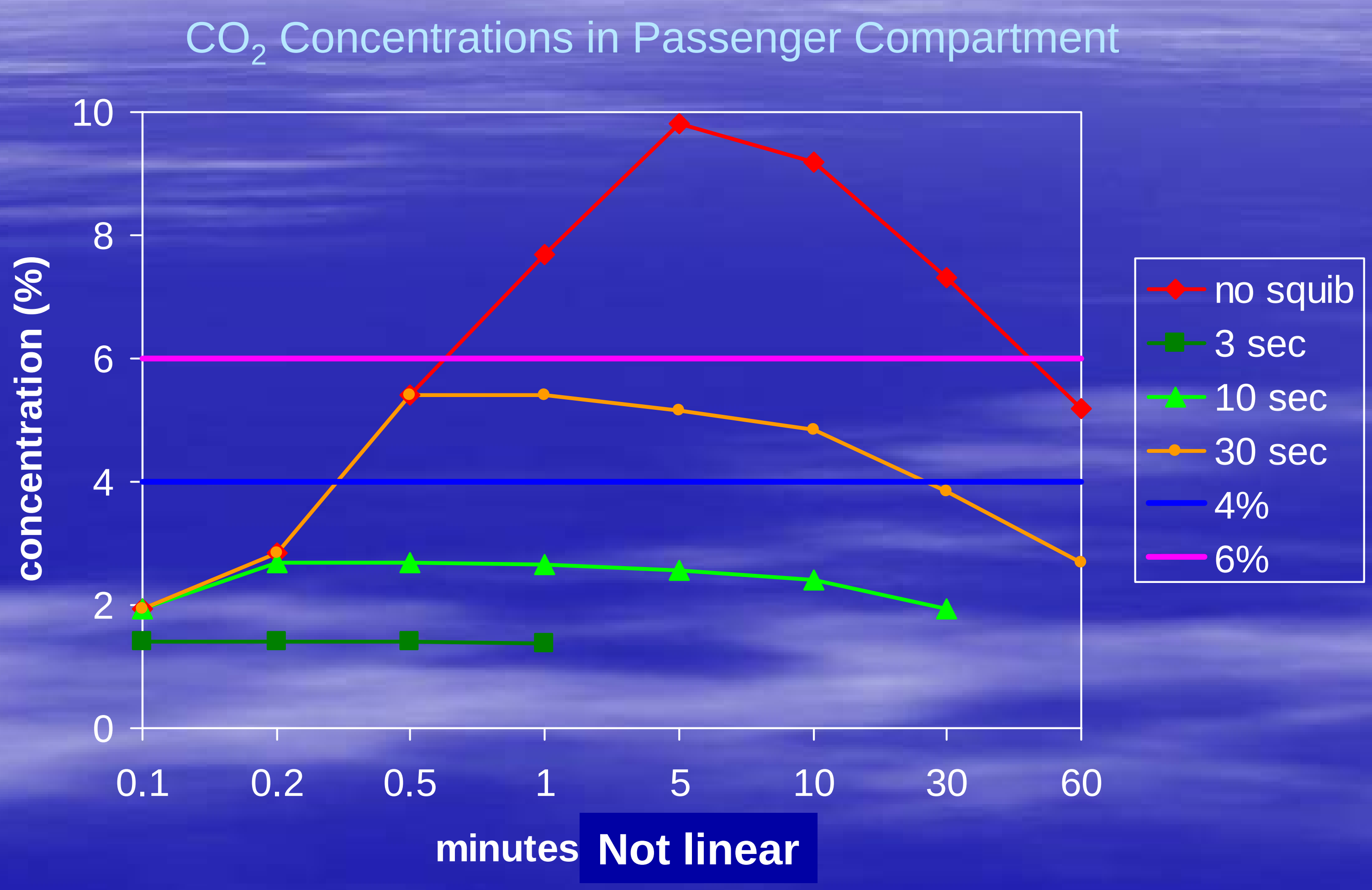
- Leak rates are predicted by model
  - Chemical specific properties
  - Pressure/temperature of system
  - Leak area size /internal geometry of system*
- Full system discharge into plenum within minutes

***Refrigerant flow from the high to low side can be constrained by the internal geometry of the system (size of components e.g. fixed orifice tube). Even if the leak in the input line is bigger than the area of the constriction, the leak rate is still limited by that flow. For this system the size of the orifice tube was selected as the maximum leak size.**

Modeling Approach

- **Simple (2D) Modeling**
  - No Mitigation (Base Case)
  - Safety engineered system where refrigerant is vented at 3,10, 30 sec. post leak
  - Different levels of air infiltration
- **CFD modeling to provide insight into localized high concentrations**
  - Focus on scenarios where reaching levels of concern is not completely answered

CO_2 : Simplified Modeling Results

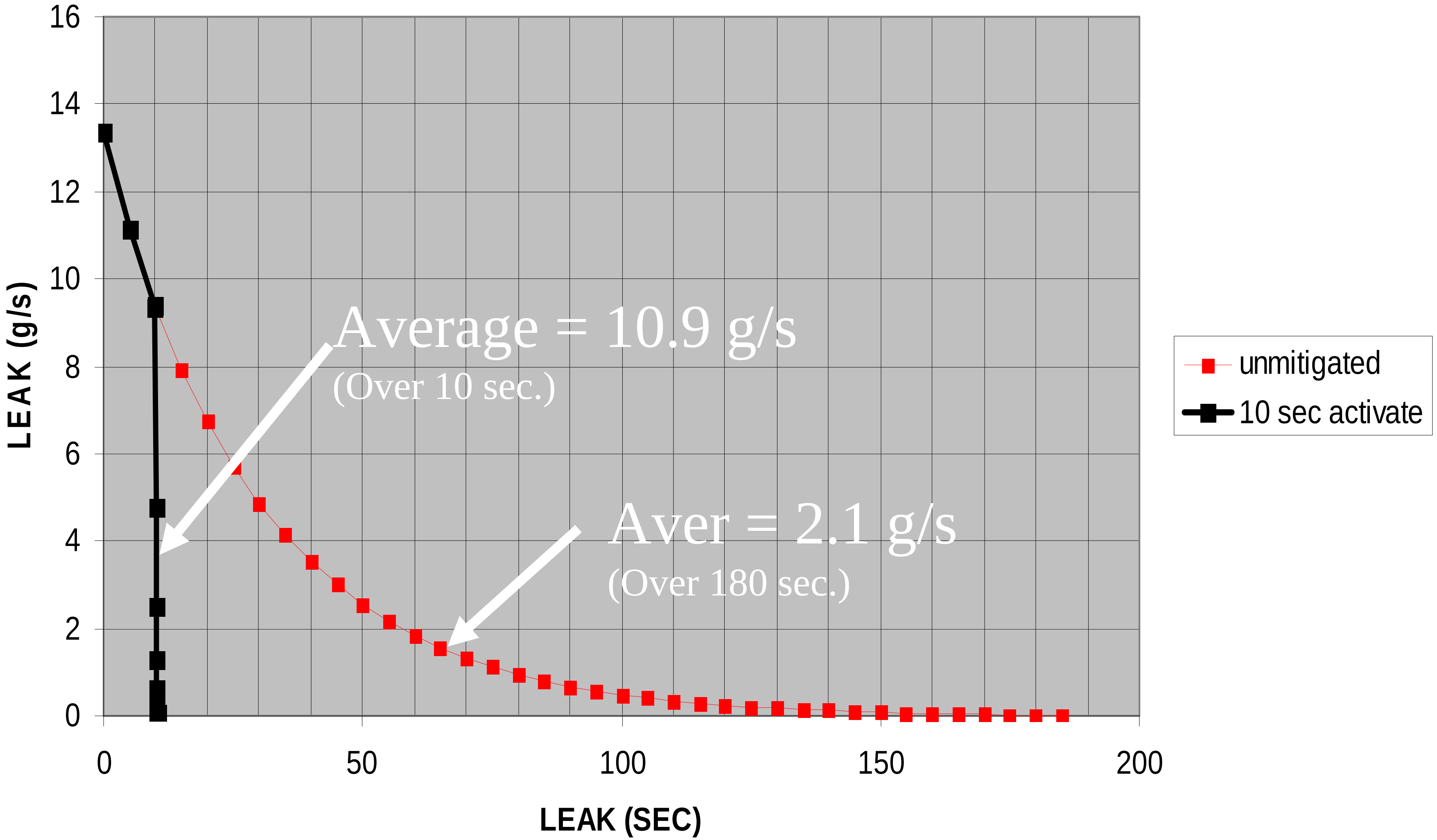


** threshold of concern is 6% for peak exposure; 4% for exposure over a few minutes

CO2, A/C on

Unmitigated: Average 2.1 g/s for 186 sec

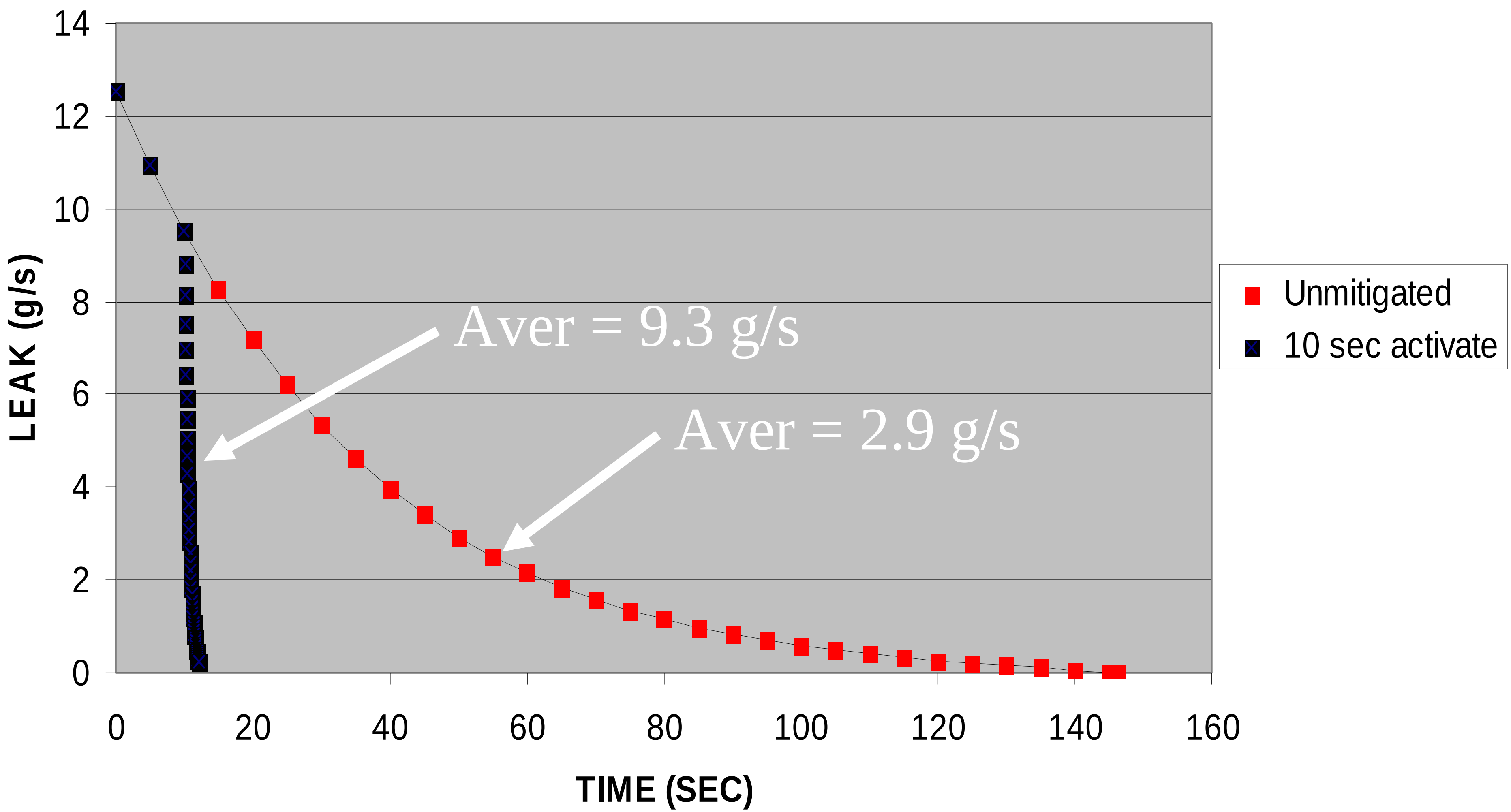
10 sec squib valve activation: Average 10.9 g/s for 10.4 sec



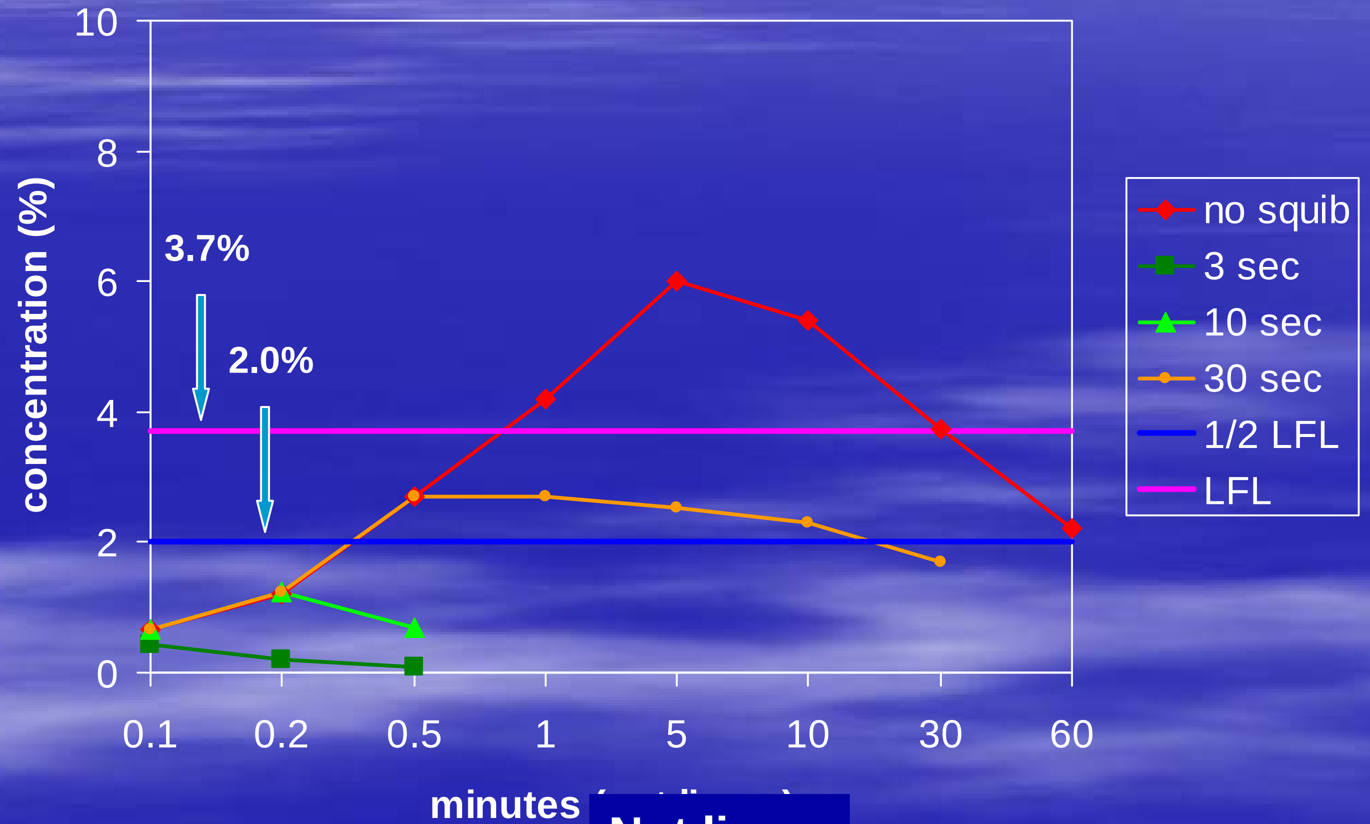
152a, A/C on

Umitigated: Average 2.9 g/s for 146 sec

10 sec squib valve activation: Average 9.3 g/s for 12.5 sec



HFC-152a: Simplified Modeling Results



Not linear

Threshold of concern = ½ LFL or 2% v/v

A/C Off, Fan On, 100% recirc, stationary vehicle

Options for Engineered Mitigation

- **Segmentation or isolation**
  - Secondary loops
  - Evaporator isolation valves (normally closed)
  - Close-coupled and hermetic
- **Detection and Response**
  - Directed release (squib valves)
  - Increased passenger compartment air exchange
  - System fault indicators (sound and dash lights)
- **Management of air exchange**
  - Baseline air exchange is a design choice
  - Fans and "ram" air can be selected
  - Controls can limit recirculation mix
- **Others…**

Fault Tree Analysis Results (assumes no mitigation)

- Passenger Exposures
  - CO_2 exposures estimated at 4300/year
  - 152a exposure with ignition source present estimated at 50/year
    - Total exposures (without ignition source present) estimated at 4300/year
- Technician Exposures
  - CO_2 exposures estimated at 2400/year (DIYers account for 40% of total risk)
  - HFC-152a exposures estimated at 1600/year (DIYers account for 20% of total risk)

Hazards to Technicians

- **Fault Tree Analysis indicates risk for both refrigerant systems**
- **Appropriately trained technicians can safely work on high pressure and fire hazards**
- **New refrigerants not suitable for DIYers**

EPA Risk Analysis Findings

- Proposed charge of CO_2 or HFC-152a could expose occupants to unacceptable risk unless mitigated
- Both systems are acceptable if technical solutions limit the concentration in the passenger compartment to safe levels.
- Technician training and certification is critical for both.

Conclusions

- Proposed charge of CO_2 or HFC-152a could expose occupants to unacceptable risk unless mitigated.
  - unacceptable concentrations reached with systems in all operating modes.
- CO_2 and 152a acceptable <u>if</u> engineering solutions limit potential passenger compartment concentrations to safe levels.

Next Steps

- US EPA
  - Finalize peer reviewed report
  - SNAP approval likely - - with safety mitigation devices, verification of specific design, component and system reliability
- Industry
  - Component and system reliability specifications/review: UL, SAE, and other appropriate standards
  - Commercialize explosion-proof HFC152a recycling machines (tested & certified by UL and others)
  - Technician training and infrastructure
  - Address risks to DIYer in MAC repair

Governmental Partners

- **Australia Greenhouse Office**
- **California Air Resources Board**
- **Environment Canada**
- **European Commission**
- **Japan Ministry of Economy Trade and Industry**

Input From Industry

- Earth Technologies Forum
  Washington DC April 2003
- SAE Automotive, Alternative Refrigerant Systems Symposium
  Scottsdale Arizona July 2003
- Mobile Air Conditioning Society
  Landsdale Pennsylvania August 2003
- Innovation in Mobile Air Conditioning Workshop
  Melbourne Australia September 2003
- Japan Industrial Conference on Ozone Protection
  Osaka & Tokyo Japan September 2003
- Japan Automobile Manufacturers (JAMA) Workshop
  Tokyo Japan October 2003
- National Highway and Transportation Safety Administration
  Washington DC October 2003
- MACS Worldwide Conference
  Orlando January 2004

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- John Rugh, NREL
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- Ed Papp, Strada Auto Repair
- Jim Taylor, MACS
- Ronald Turner, Ridge Auto & Truck
- Juergen Wertenbach, Daimler Chrysler
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